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TITLE A PROPOSED METHOD FOR REMOTE THERMOMETRY IN TURBINE ENGINES

AUTHOR(S): B. W. Noel, M. R. Cates,* S. W. Allison,* H. M. Borella,**,
L. A. Franks,** and B. R. Marshall**

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*Oak Ridge Gaseous Diffusion Plant
**EG&G Santa Barbara Operations

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ABSTRACT

A Proposed Method for Remote Thermometry in Turbine Engines

B. W. Noel

Los Alamos National Laboratory, Los Alamos, NM 87545

M. R. Cates and S. W. Allison

Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN 37831

H. M. Borella, L. A. Franks, and B. R. Marshall

EG&G Santa Barbara Operations, Goleta, CA 93117

Introduction

A method developed recently for measuring temperatures remotely in operating gas centrifuges^{1,2} may be adaptable to similar measurements in operating turbine engines.³ The method uses laser-induced fluorescence (LIF) from a pulsed uv laser to excite a rare-earth-oxide phosphor that is bonded in a thin layer to the surface to be measured. The luminescent decay times of certain spectral lines are well-behaved functions of temperature. These lines can therefore be used to measure the temperature with considerable accuracy (within 0.3°C in the centrifuge, near room temperature).

The first questions to be answered in a study are the following.

1. Is there a phosphor whose LIF is usable at the desired temperature?
2. If so, is it chemically nonreactive at that temperature and stable over multiple temperature cycles?
3. If there a suitable way to bond the phosphor to the alloys used in turbine engines such that it will adhere through temperature cycling and at speed?

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Given positive answers to these questions, there remain many engineering questions to be considered later.

In this paper we discuss initial experimental results on the first question and speculate about answers to the other two questions.

Experimental Technique and Results

An experiment was set up, as shown in Fig. 1, to measure the decay lifetime of the 612-nm line emitted from LIF of europium-doped yttrium oxide over the range from 300°C to the maximum obtainable from the oven, 930°C. A small hole was drilled in the stainless-steel case of the ceramic heater cartridge. A chromel-alumel thermocouple was mounted in the hole, flush with the surface. The phosphor was applied to the area around the hole. The oven chamber containing the cartridge was flushed with dry nitrogen during operation to minimize corrosion of the stainless steel. The LIF from the phosphor is excited by 337.1-nm radiation from the N_2 laser that was brought into the oven via an optical fiber. The LIF was focused on the entrance slit of the monochromator, which was used to select the 612-nm line. The same setup was used with the monochromator in its scanning mode to locate candidate spectral lines. The data from many laser pulses at a given temperature were gathered and analyzed by the Biomatron transient recorder and the Tektronix waveform-processing oscilloscope.

The results are shown in Fig. 2. Above 700°C, the data are linear on a semilog plot, showing the desired well-behaved characteristic. The 612-nm line from this phosphor is not usable below 700°C, but there are other lines that are useful in this range.

The experimental setup is presently being modified to expand the temperature range to our goal of 1150°C.

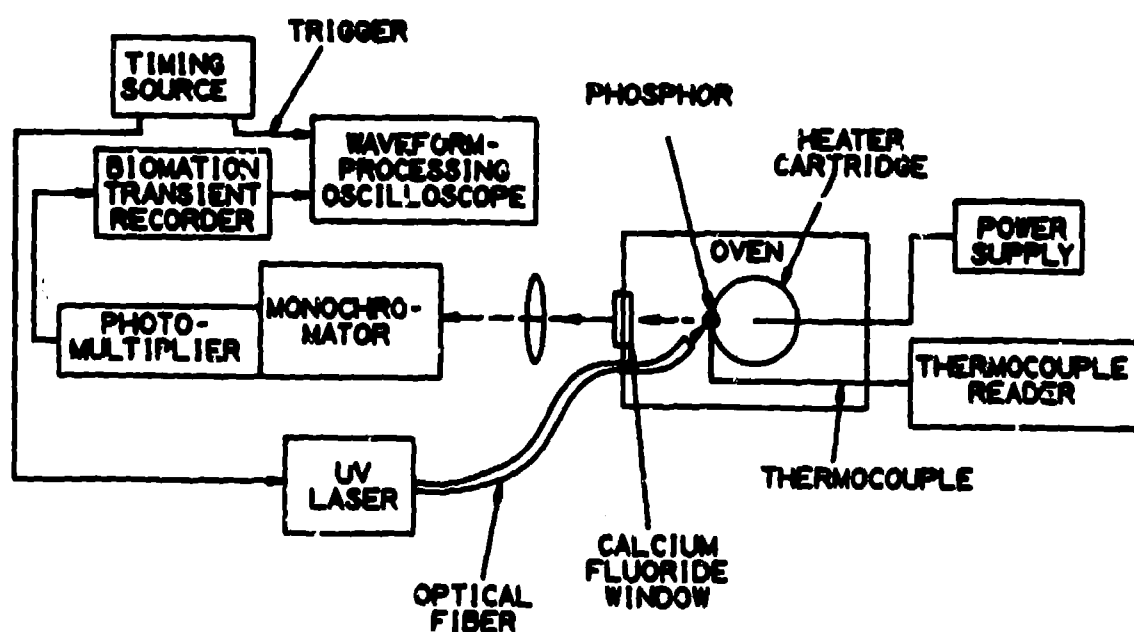


Fig. 1. Experimental setup for measuring pulsed laser-induced-fluorescence decay lifetime as a function of temperature for europium-doped yttrium oxide.

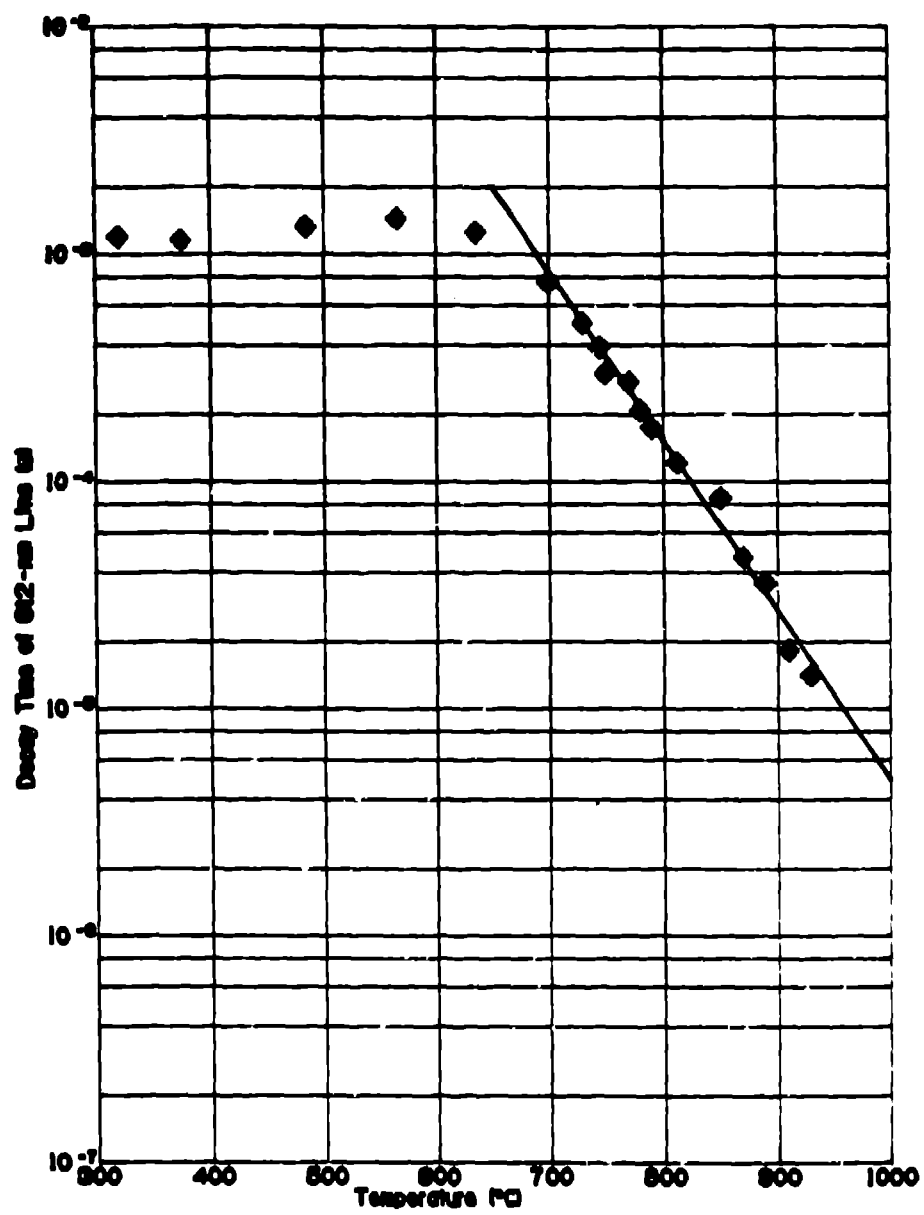


Fig. 2. Experimental results from setup in Fig. 1.

Speculations

The yttrium oxide, a ceramic, appears to be chemically inert to above 925°C. Whether it will be stable over several temperature cycles, or whether the europium dopant atoms will diffuse out, has not yet been determined.

Several bonding methods for high temperatures have been considered. These include sodium and potassium silicates, glass frits, sputtering, flame spray, and a new photoresist technique.⁴ Preliminary results show that the silicates are transparent to uv and can easily be sprayed. However, they are difficult to outgas completely of their trapped water vapor. It may be possible to improve this with a vacuum oven.

References

1. M. R. Cates, et al., "Remote Thermometry of Moving Surfaces by Laser-Induced Fluorescence of Surface-Bonded Phosphor," ICALEO '83 Proceedings: Inspection, Measurement, and Control 39, 50-55 (1983); also UCC-ND Report K/TS 11,232 (1983).
2. M. R. Cates, et al., "Applications of Pulsed-Laser Techniques to Dynamic Thermometry of Rotating Surfaces," presented at ICALEO '84, Boston, November, 1984, and to be published in ICALEO '84 Proceedings.
3. B. W. Noel, letter to William Stange, AFWAL/POTA, June 1984 (unpublished).
4. R. A. Lemons, Los Alamos National Laboratory, personal communication to B. W. Noel, November 1984.

Wish to submit an abstract for (conference/meeting): 21st Joint Propulsion Conference

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|--|--|
| <p>1 Author presenting paper B. W. Noel, Staff Member
Nonmember (505)667-2615
Los Alamos National Laboratory, MS 678
P.O. Box 1663, Los Alamos, NM 87545</p> | <p>2 M. R. Cates & S. W. Allison, Staff Members
Nonmembers
Oak Ridge Gaseous Diffusion Plant, MS 180
P.O. Box P, Oak Ridge, TN 37831</p> |
| <p>3 H. M. Borella, L. A. Franks,
& B. R. Marshall, Staff Members
Nonmembers
EG&G Santa Barbara Operations
130 Robin Hill Rd, Goleta, CA 93117</p> | <p>4</p> |

Abstract due date: November 15, 1984

Draft of paper included? ☐ Yes ☒ No

Similar results been presented or published elsewhere? ☐ Yes ☒ No

Concise statement of problem (its genesis and objective covered):

A proposed technique for remotely measuring temperatures of moving and stationary rotor and stator components in operating turbine engines

Scope and methods of approach, with statement of contribution to the state-of-the-art or an application of existing analytical techniques and theories to a problem:

Based on a method we developed recently to measure temperatures in a gas centrifuge operating near room temperature in a vacuum. Extension to turbine temperatures, pressures, and materials by investigating high-temperature phosphors and bonding methods.

Summary of important conclusions:

Initial data are brand-new, so not yet extensive. Conclusion so far is that at least one phosphor, europium-doped yttrium oxide, is usable to 950°C.

Statement of data used to substantiate conclusions, and freshhand sketches of major figures to be used (no more than two typed pages):

See abstract.